POLONIUM-210 AND DRINKING WATER: OCCURRENCE IN MINNESOTA AND HEALTH RISK IMPLICATIONS

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MINNESOTA MDH DEPARTMENT OF HEALTH

CLEAN WATER LAND & LEGACY AMENDMENT

Special Note

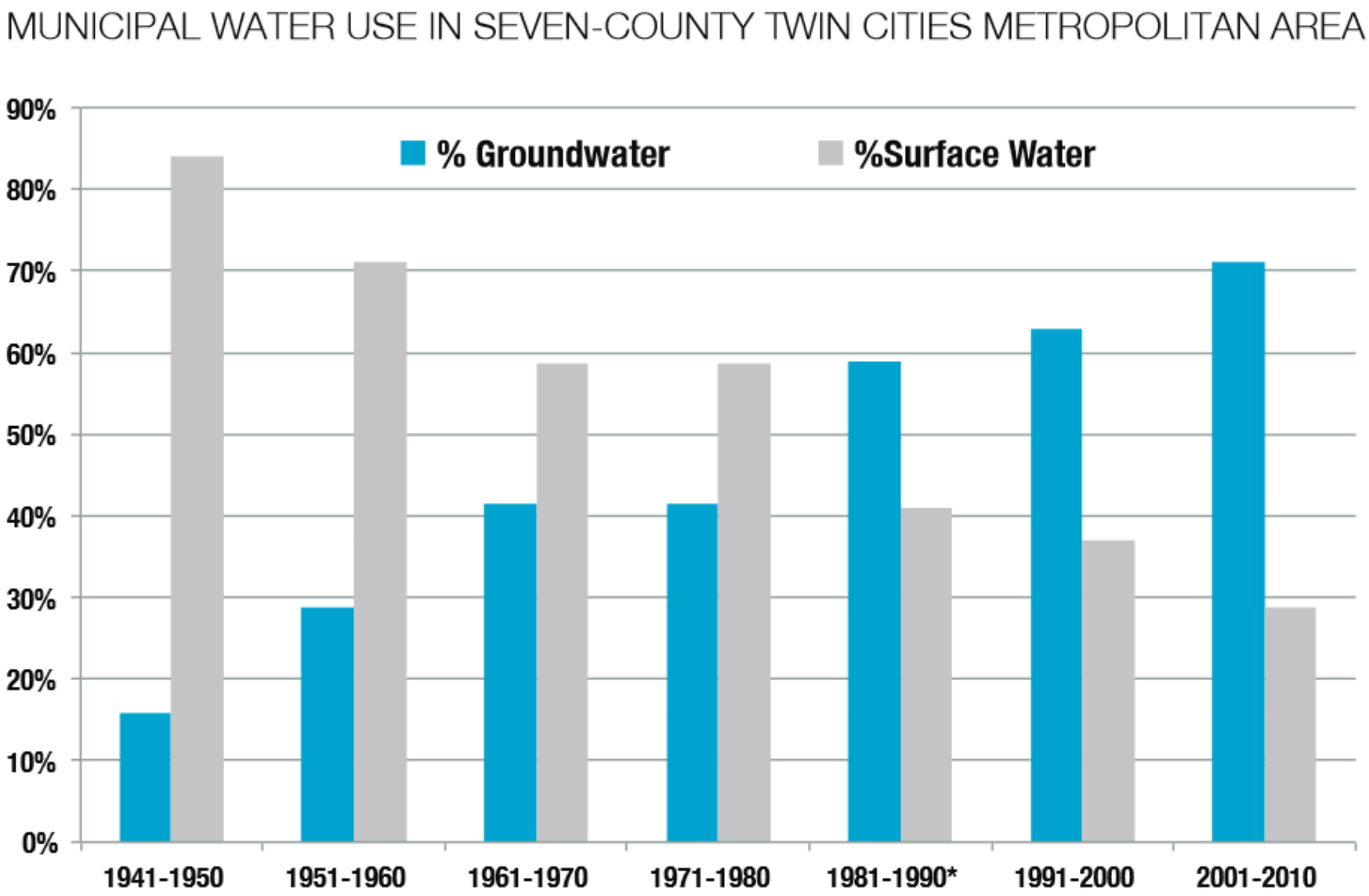
- MDH has not developed a specific policy or interpretation of the exposures and risks to date

- Po-210 occurrence in groundwater is an ongoing project under the Minnesota Department of Health's Contaminants of Emerging Concern (CEC) program: http://www.health.state.mn.us/cec

Focus

- Polonium-210 (Po-210) and other Naturally-occurring radionuclide materials in MN drinking water sources
- Cancer is the major health risk, low level exposures
- Groundwater used for drinking water
- Minnesota and northern Midwestern states are known for elevated radionuclides in soil and groundwater

Groundwater Use Increasing



www.metrocouncil.org

Cumulative Exposure is Key

- Small doses of radiation, over the course of a lifetime, cumulatively increase risk of cancer

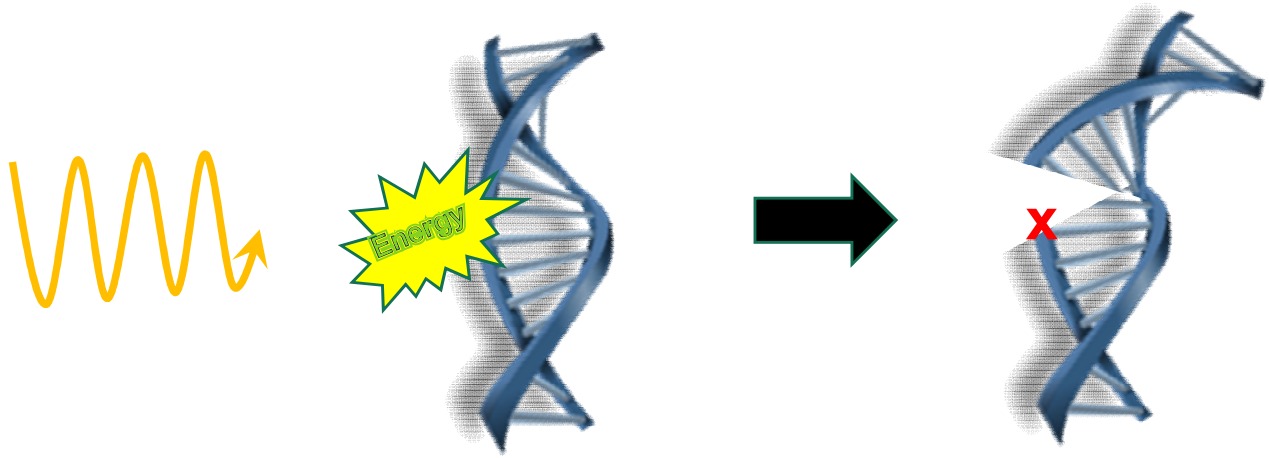
- Higher intake/body weight ratio in children results in higher doses in early life *(J. Radiol. Prot. 35 (2015) 1)*
  - Age-specific dose coefficients used with average national water consumption rates
  - Risks from Po-210 and Pb-210 not included in overall risk estimates from Federal Register, 2000

- Therefore, limiting exposure where possible is important for public health

- Limiting most potent exposures even more critical (α)

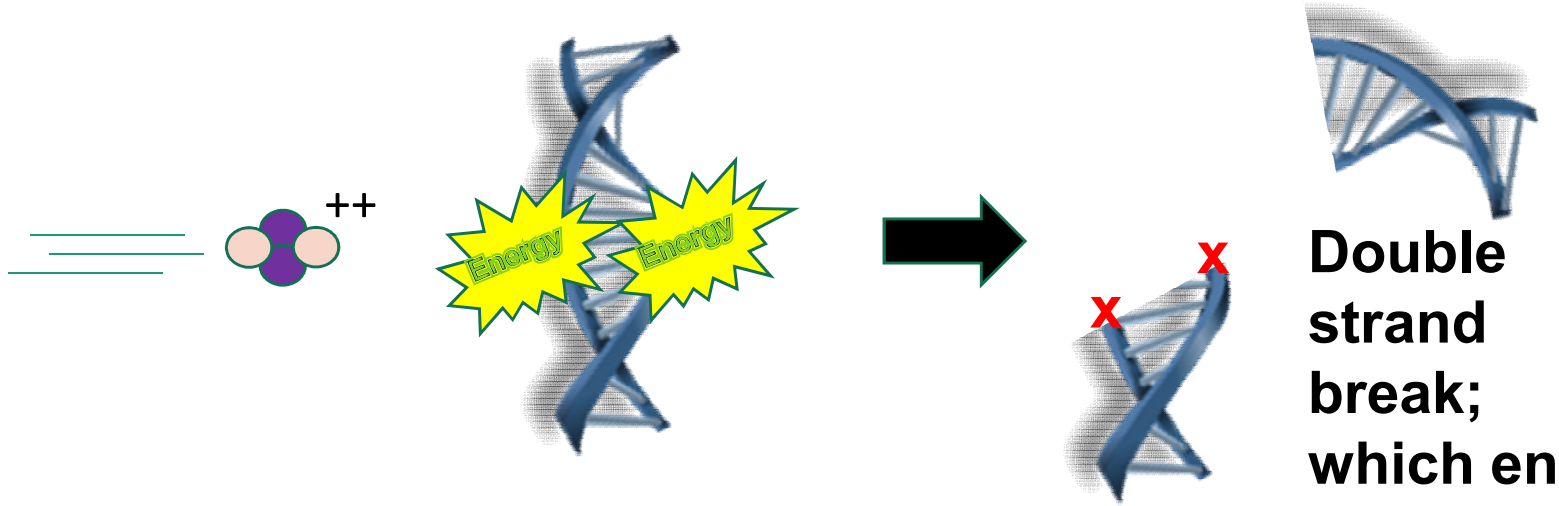
Mechanism of Toxicity: Breaking DNA

Sparsely Ionizing (wave)



Single strand break; easy fix

Densely Ionizing (particle)



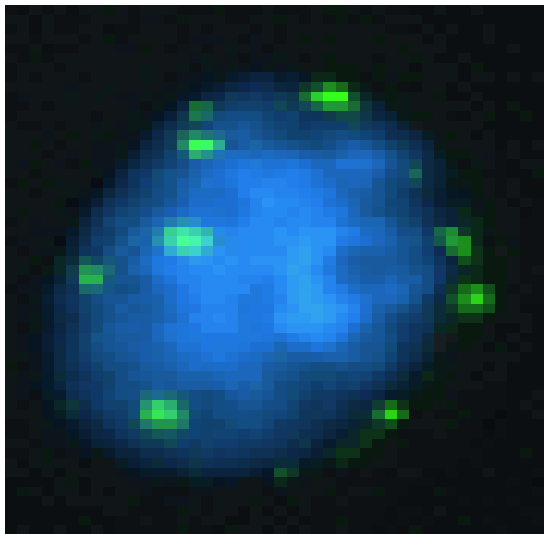
Double strand break; which end is up??

Radiation Toxicity Paradox

- **Short-range alpha radiation is more damaging (20x) than deeply penetrating gamma radiation**
- Densely clustered radiation damage problematic, a real mess
- X-ray/Gamma ray damage is spread out, easier to repair
- Alpha particles produce difficult to repair damage even at low doses

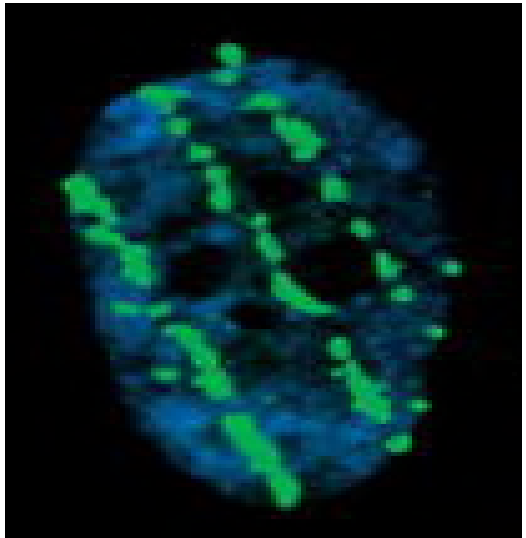
Sparsely Ionizing

X-rays & Gamma rays



Densely Ionizing

Alpha Particles

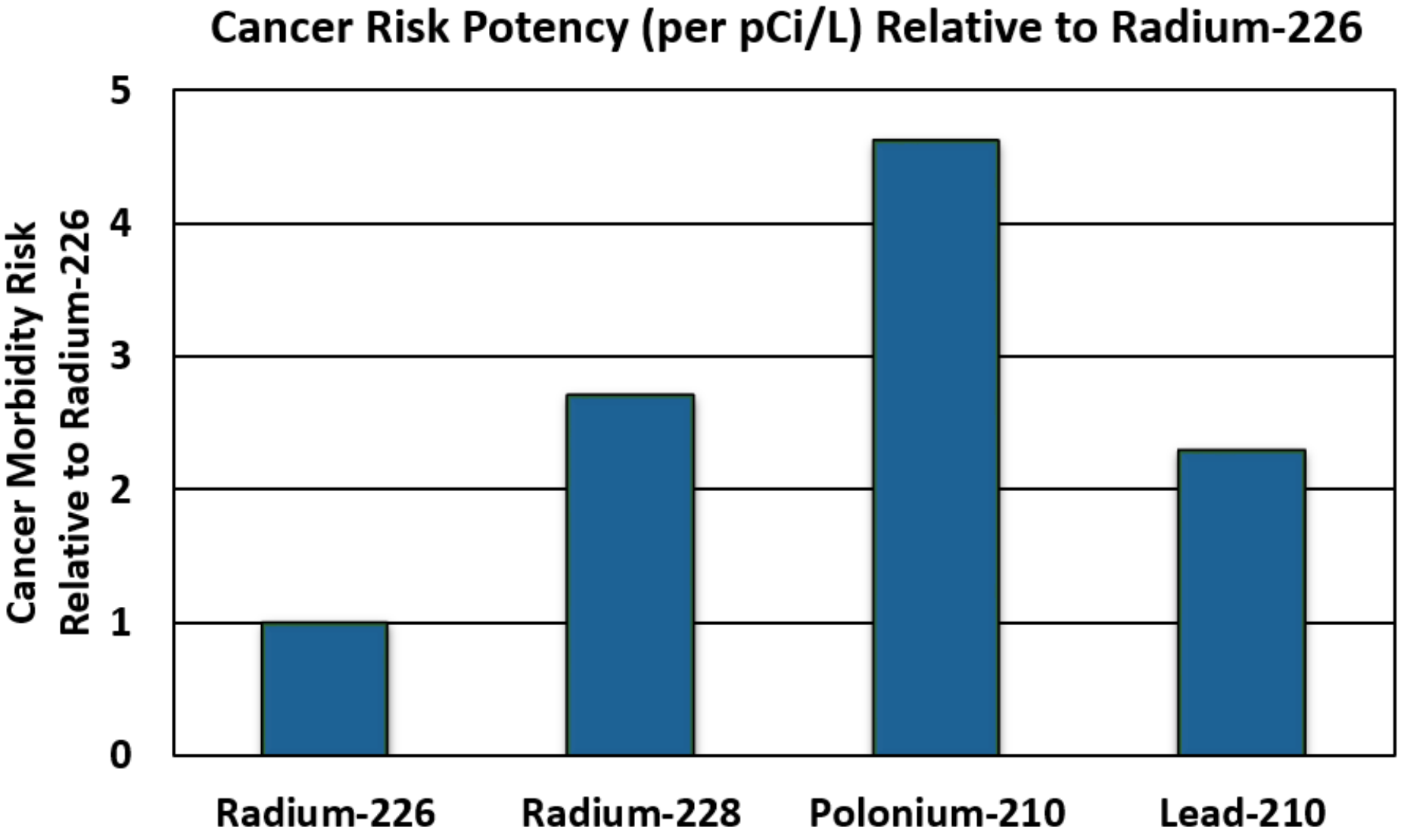


Radiation Research
164(4):518-522. 2005

Why Focus on Po-210?

- Potent alpha emitter and known human carcinogen
  - Biological half-life of ~50 days
  - Readily taken up by GI tract, especially in children
  - Partitions to organs and tissues, rather than bone
- Scant data on Po-210 in drinking or ground water
- Radium-226, 'parent' of Po-210, elevated in Minnesota
- Gross alpha elevations could be due to Po-210 levels
- EPA stated in Federal Register (2000) that monitoring was required for Po-210, but no new comprehensive study completed since addition to UCMR in 2000 (method issues)

Relative Potency of Selected Radionuclides



Pilot Study Design, Po-210 and Pb-210

- Selected sampling sites based on elevated gross alpha levels known from compliance monitoring
- 32 source water samples spread across various aquifers
  - 4 entry point (post-treatment) samples
  - Split sampling at five sites with USGS to examine interlab var.
  - Single grab samples, unfiltered
- Paired gross alpha time course analysis with Po-210
- 10 samples were also analyzed for lead-210 (this can reveal clues about the origin of the Po-210)

Summary of Overall Results

Analyte	Mean (pCi/L)	Median (pCi/L)	Maximum (pCi/L)	Detection % (> 0.1 pCi/L)
Polonium-210	0.39	0.13	5.0	67%
Gross Alpha (30 day)	28	25	88	97%
Lead-210	0.75	0.44	2.9	50%

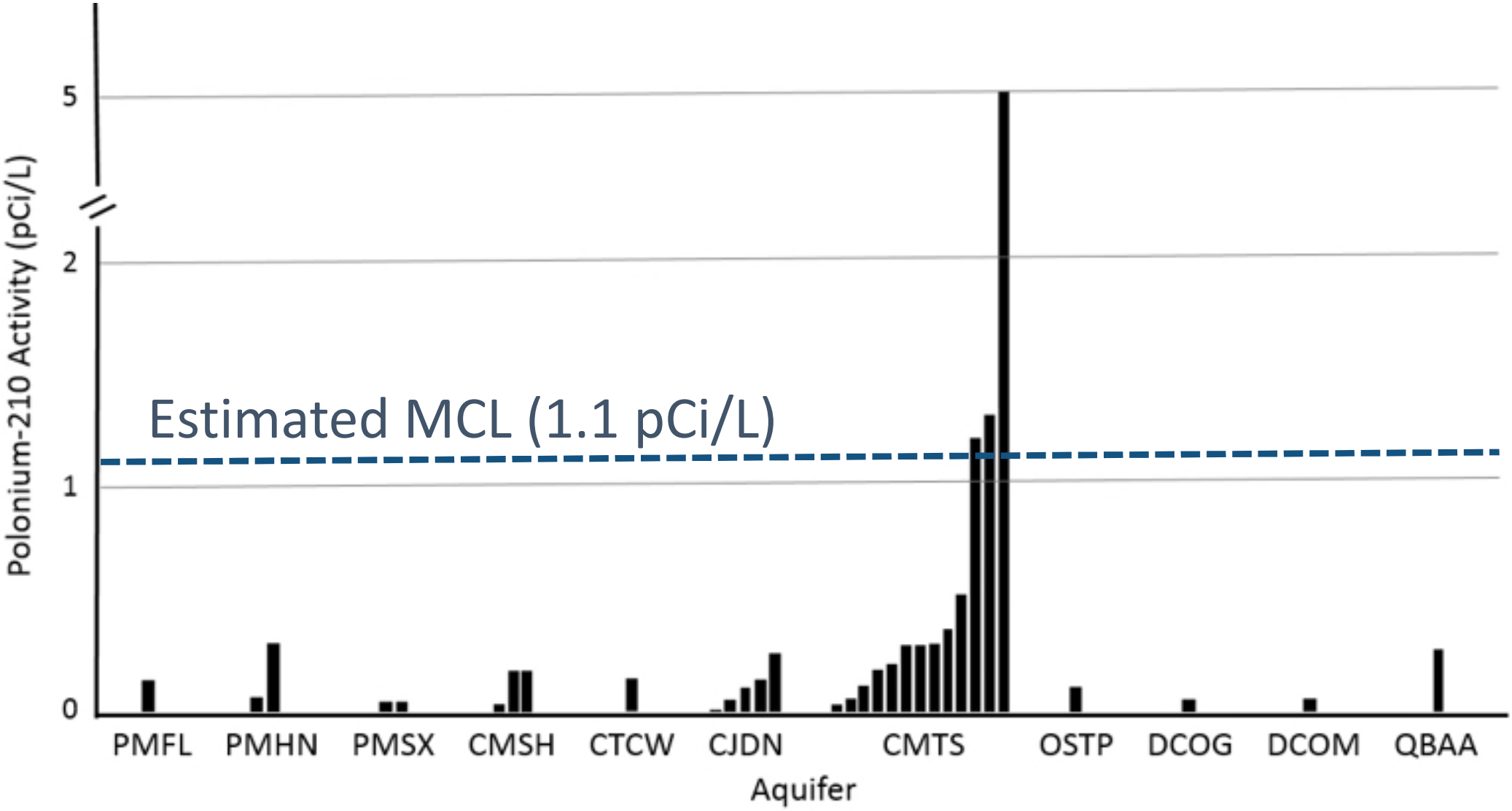
High Pb samples and high Po samples: not the same samples!

Po-210 and Pb-210 Results

Well #	Po-210 (pCi/L)	Pb-210 (pCi/L)
430604	4.99 (±0.75)	0.551 (±0.31)
415943	1.33 (±0.09)	0.326 (±0.18)
241335	1.23 (±0.21)	0.702 (±0.32)
151559	0.528 (±0.13)	--
645355	0.371 (±0.09)	0.631 (±0.26)
Entry Point #3	0.334 (±0.09)	2.870 (±0.41)
206456	0.308 (±0.09)	0.120 (±0.17)
Entry Point #1	0.232 (± 0.08)	1.52 (± 0.28)

No equilibrium between Po and Pb

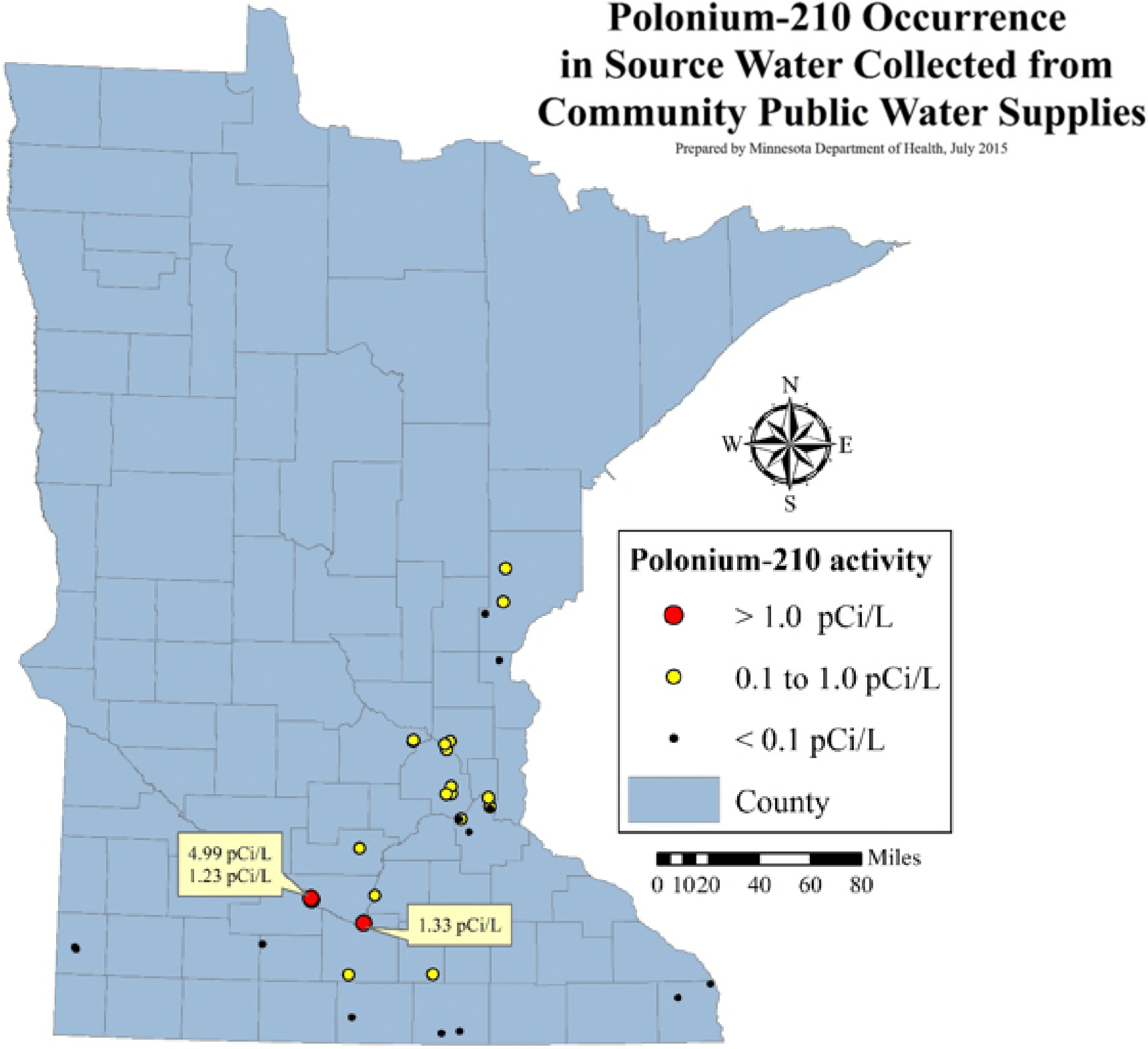
Po-210, By Aquifer (raw water only)



Aquifer acronyms: CTCW (Tunnel City-Wonewoc), CJDN (Jordan), CMSH (Mt. Simon-Hinckley), CMTS (Mt. Simon), DCOG (Cedar Valley-Galena), DCOM (Cedar Valley-Maquoketa), PMFL (Fond du Lac Formation), PMHN (Mt. Simon-Hinckley), PMSX (Sioux Quartzite), OSTP (St. Peter), QBAA (Quaternary buried artesian aquifer). 32 Source Water Wells.

Polonium-210 Occurrence in Source Water Collected from Community Public Water Supplies

Prepared by Minnesota Department of Health, July 2015



Major Findings

- Po-210 is found at low levels in many aquifers, with highest levels found in Mt. Simon
- Highest levels found in relatively shallow Mt. Simon wells
- Two post-treatment samples contained highest activity of Pb-210
- Po-210 was found in three source wells above 1 pCi/L, with a maximum detection of 5 pCi/L

Health Risk Assessment

- Po-210 risks between 1:100,000 (within the acceptable risk range) and 1:2,000 (outside of range) – assuming activity relatively constant over time

- How to address Lead-210? It is a beta emitter but a major component of its dose comes from decay to Po-210/alpha

- Is it time for a true Mixture risk assessment for additivity of all naturally-occurring radionuclides?
  - Is the benchmark 4 mrem/yr total exposure (per Safe Drinking Water Act)?
  - For Minnesota: Ra-226+Ra-228+Po-210+Pb-210 = how much risk acceptable?

- 'Natural' Radionuclides, considerably more risk than most chemicals
  - Regulation of Radionuclides at a 1:10,000 cancer risk level is ten times higher risk level than the 1:100,000 cancer risk level we use at MDH for synthetic chemicals
  - We find radionuclides far more often in groundwater than most chemicals
  - Treatment is common, but its effects on Po-210/Pb-210 unclear

Future Steps

- Follow-up at locations with >1 pCi/L of Po-210 or Pb-210
- Determine effect of treatment at these sites
- Is radon supporting Pb-210 formation in DW treatment plant effluent?
- Can domestic wells (typically shallower) contain Po-210 >1 pCi/L?
- Lack of lab capacity for Po-210 and Pb-210 makes progress difficult

Acknowledgements

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MDH

Minnesota Department *of* Health

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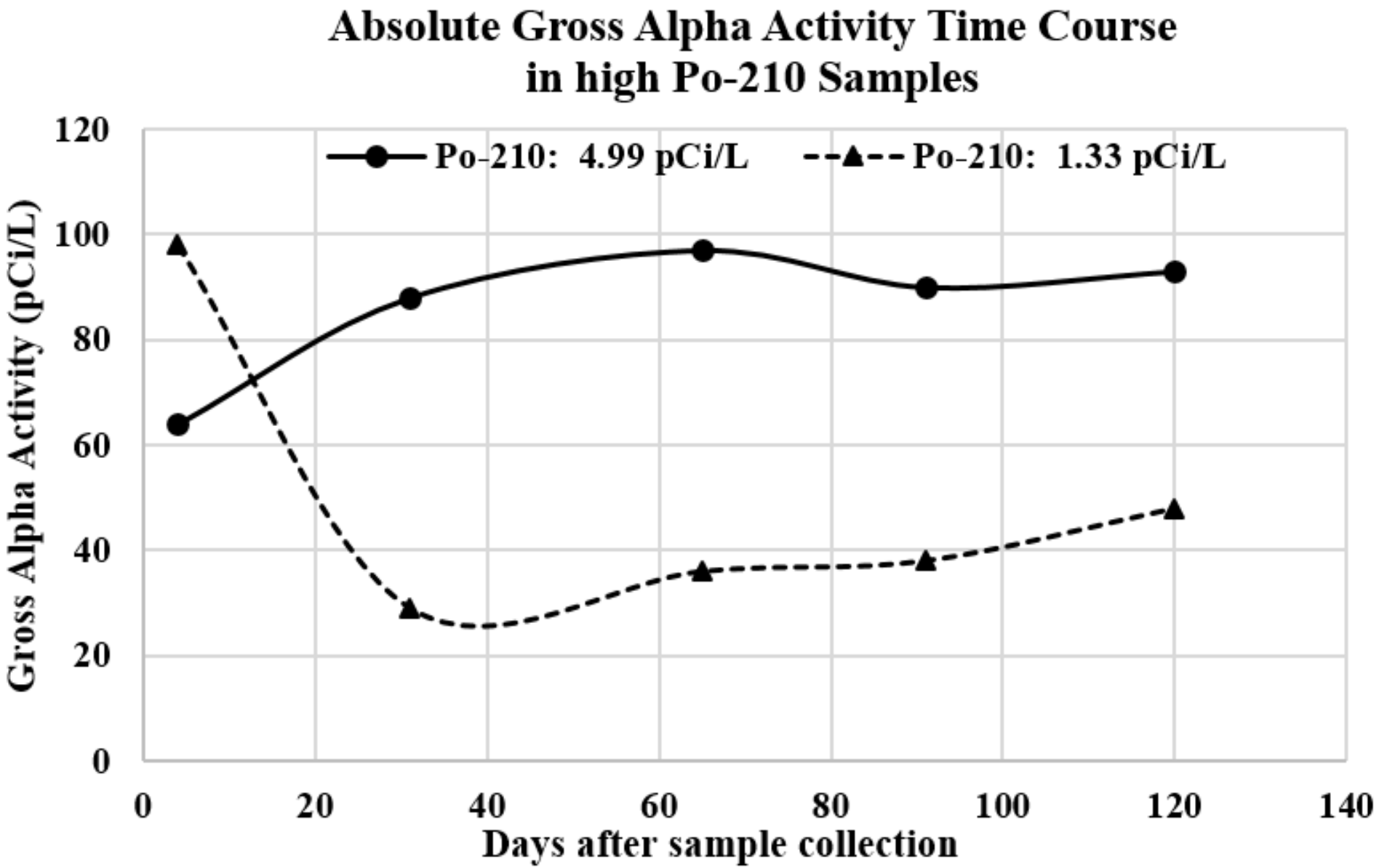
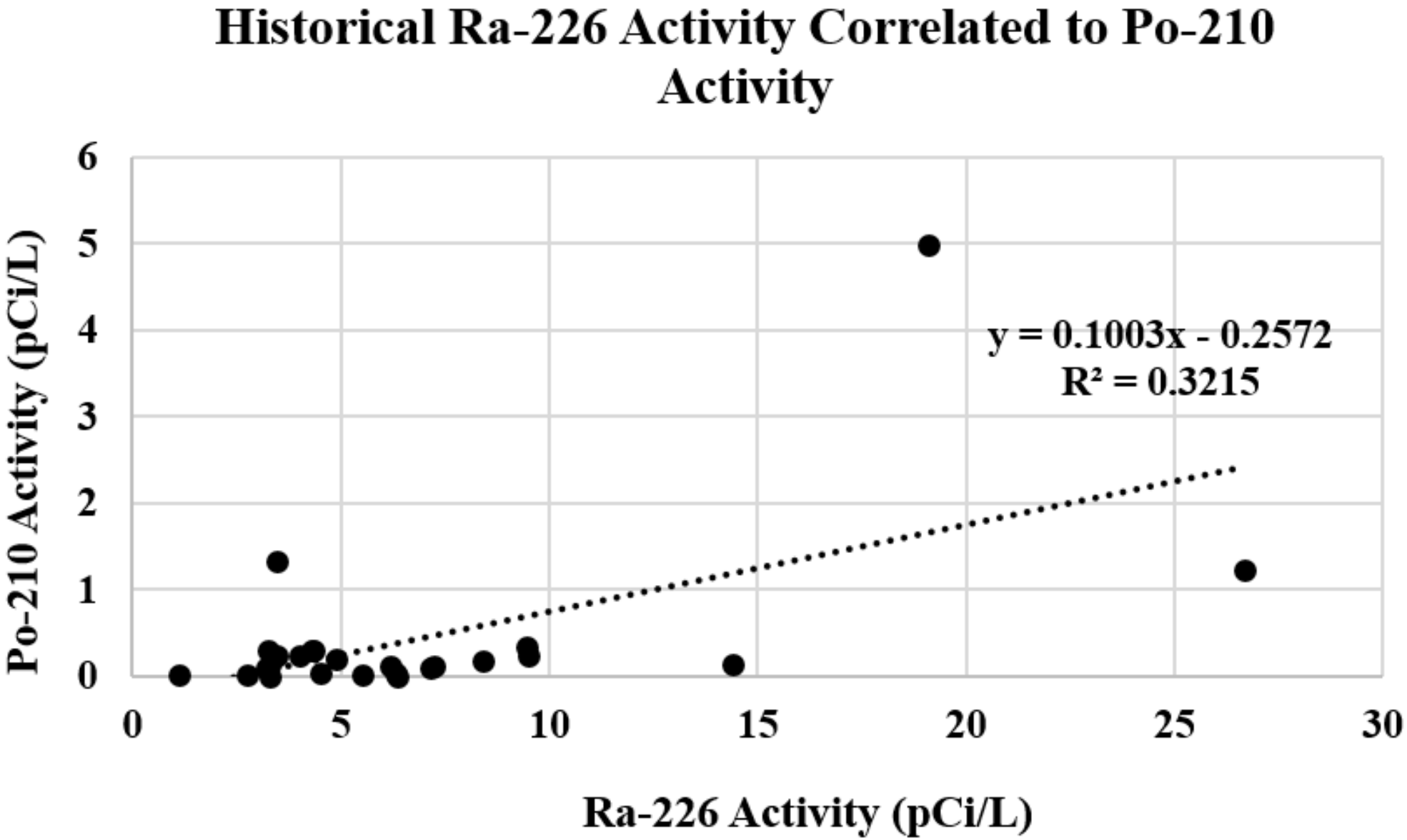
Minnesota Department of Health http://www.health.state.mn.us/cec

Supplemental Material

Gross Alpha trends over time



Correlation with Radium-226 (Historical data)



Ra-226/Ra-228 ratio and Po-210